The Study of Non-Metallic Screen Application In Coal Bed Methane (CBM) Well

by

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13875

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CERTIFICATION OF APPROVAL

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Approved by;

____

(Dr. Sonny Irawan)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is on my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources of persons.

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(WAN AMIRUL MUKHRIZ BIN WAN MUHAMAD)

ABSTRACT

This study is about cost saving initiative (CSI) in reducing the high completion cost of the steel slotted screen pipes in coal bed methane wells and also to provide a theoretical study of low intensity non-metal completion pipes, then to perform lower cost screen completion. The main problem is the high completion cost of steel-slotted tubing in completion and improper selection of slot density and slot width. This paper adopts survey to measure the collapse resistance of non-metallic pipe using Universal Testing System (UTS) and make analysis about the relationship between the slot density and slot width with the collapse resistance and at the end, to provide comparative analysis between the cost of non-metallic and metallic screen pipe. The polyvinyl chloride (PVC) Schedule 80 pipes are used as the non-metallic in the study due to its strength and low weight. The study shows that, the collapse pressure is affected by the slot density and slot width as the pipe collapse pressure is inversely proportional for both of them. Apart from that, this research also study about the suitability of the non-metallic screen pipe to be installed in coal bed methane, by comparing the collapse resistance and reservoir pressure of three different case studies. In theoretically, non-metallic screen pipe can be installed in the coal bed methane and the cost of the non-metallic screen completion is lower than the cost of the metallic screen completion.

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CHAPTER 1

INTRODUCTION

1.1. Background Study

At present, coal bed methane well (CBM) becomes more popular and rapidly became one of important natural gas resource all around the globe. Due to its shallower depth compare to the conventional gas well, CBM well have been developed throughout the years as the alternative of the conventional gas and perhaps, within years, this type of gas will become the main source of energy for all around the globe. The CBM well completion method which mainly consist of drilling, casing installation, cementing, perforation and fracturing, integrated completion, work over and maintenance, then into the production stage may cause several damages to the well such as low well integrity, well collapse and sand production problem, which become the main concern throughout the life of the well. The failure of controlling sand production may lead into uncontrollable amount of sand production which later on can cause lot of problem such as reduced efficiency of the equipment and equipment failure. Without a proper mitigation step, uncontrollable amount sand production can even kill the well due to total blockage of the pore spaces. The usage of sand control either mechanically or chemically is important in tackling such problem. One of the way to tackle the problem is the usage of screen pipe which solve the sand problem mechanically by screening the fluid and block the sand from penetrating into the wellbore. The screen completion method is effectively can prevent the sand from penetrate into the wellbore and the collapse of borehole in an unconsolidated formation reservoir such the coal bed methane reservoir. Basically, the screen pipe is made up of the steel which is known for its high cost. Thus, the total of the well completion cost will be high. So, by the introduction of non-metallic screen pipe usage such as PVC screen pipes, the well completion cost will be lesser and revenue can be maximized as the non-metallic screen pipe is lower in cost compare to the metallic.

1.2. Problem Statement

- **High cost of coal bed methane well completion.**

Due to the usage of steel pipe throughout the completion, the total cost of coal bed methane well completion is really high and this will minimize the well revenue. In order to maximizing the total revenue, an alternative to the steel pipe should be determine which is lower in cost compare to the steel, to perform low-cost completion as long as the pipe can withstand the reservoir pressure.

- **Improper slot width and density selection.**

The slotted screen pipe should be optimized in terms of slot width and slot density to find the suitable screen pipe feature in order to withstand the reservoir pressure. Too wide slot width or too high slot density can reduce the pipe collapse resistance, thus making the pipe unable to be installed in the reservoir. A study of the relationship between slot width or slot density with collapse resistance should be done.

1.3. Objective

This project aims:

- To study the relationship between the slots densities on the pipe with the pipe collapse resistance value.
- To study the relationship between the slots widths on the pipe with the pipe collapse resistance value.
- To provide a comparison between non-metallic and metallic screen pipe in term of capital expenditure.

1.4. Scope of Study

- Cost saving initiative (CSI) study regarding to the cost of well completion.
- Coal bed methane (CBM) reservoir and vertical well completion.

- Laboratory flexural testing (collapse resistance test) using Universal Testing System (UTS).
- Using polyvinyl chloride (PVC) schedule 80 in laboratory flexural testing.
- Cost estimation and comparison between the metallic and non-metallic in term of capital expenditure (CAPEX)
- Three case studies; San Juan basin and Powder River basin in United States, Sarawak Coalfield, Malaysia

1.5. Feasibility Study

A maximum 28 weeks have been allocated to complete this study which is two semester and the student should complete the assigned project within this period. In terms of feasibility, the author found that this project is feasible and can be completed based on the job scopes within the given time.

CHAPTER 2

LITERATURE REVIEW

2.1. Coal bed methane

Basically, coal is one of the sedimentary rock which is in combustible black or brownish-black in color, and mainly the composition of carbon along various quantity of other elements such as hydrogen, nitrogen, sulfur and oxygen [1] and it is formed by the plant material compaction and decomposition which is called the coalification process as shown in figure 1 below. Throughout the this process, the gases mainly methane, nitrogen, and others are generated and then these gases either absorbed on to the surface of coal or trap within the pore spaces around the seam or layer of the coals. This coal bed methane gas or also as known as coal seam gas (CSG) shows an attractive and abundant natural gas source in several parts around the world, for instance Australia, India, China and United States. Due to its relatively low costs of extraction and economically advantageous, this type of gas becomes a significant feed for power generation plants and petrochemical as well.

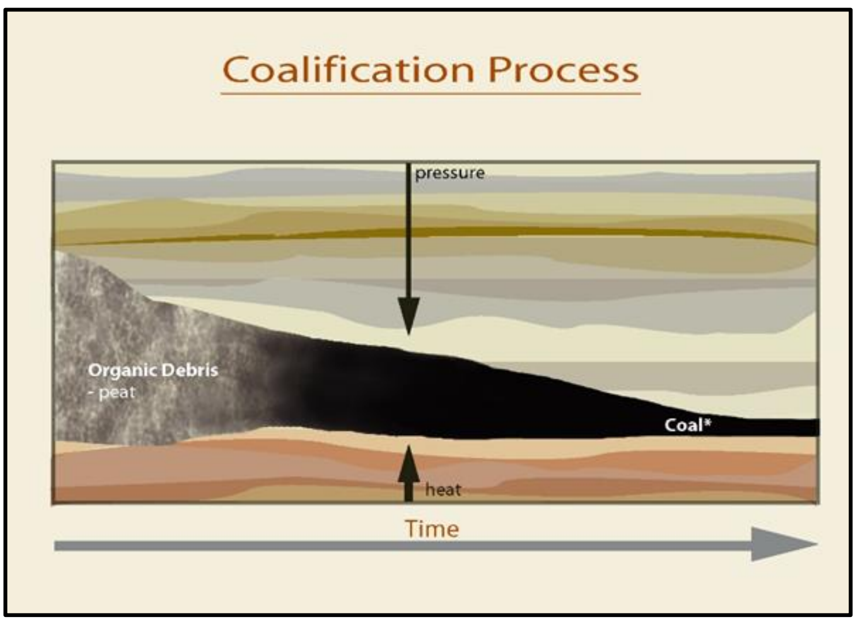

FIGURE 1: Coalification Process [2]

Coal seam gas is one of the natural gas produced from the coal itself. It is same like other natural gas in which can use as the source of energy in home appliances and also have commercial applications, for instance, the generation of electricity. But the only difference between the coal seam gases with other natural gases is by the way the coal seam gas is formed; by nature. The table 1 below shows the differences between coal bed methane and the conventional gas.

TABLE 1: Comparison between coal bed methane and conventional gas [2]

Characteristics	**Coal Bed Methane @ Coal Seam Gas**	**Conventional Gas**
Gas generation	Gas is generated and trapped within the coal layer	Gas is generated in the source rock and the migrates into the reservoir
Structure	Uniformly-spaced cleats	Randomly-spaced fractures
Gas storage mechanism	Absorption	Compression
Transport mechanism	Pressure gradient (Darcy's Law)	Pressure gradient (Darcy's Law)
Production performance	Gas rate increases with time then declines. Initially the production is mainly water. GWR increases with time.	Gas rate starts high then decline. Little or no water initially. GWR decrease with time
Mechanical properties	Young Modulus ~10^5 N/m^2 Pore compressibility ~10^{-4} psi^{-1}	Young Modulus ~10^6 N/m^2 Pore compressibility ~10^{-6} psi^{-1}

2.2. Global View of Coal Bed Methane Gas

Nowadays, coal bed methane gas (CBM) or as known as coal seam gas becomes more popular and rapidly become one of important natural gas resource all around the globe as the demand to this type of gas keep increasing from time to time. The figure 2 shows that the production of the gas is keep increasing parallel to the demand either for domestic usage or exports.

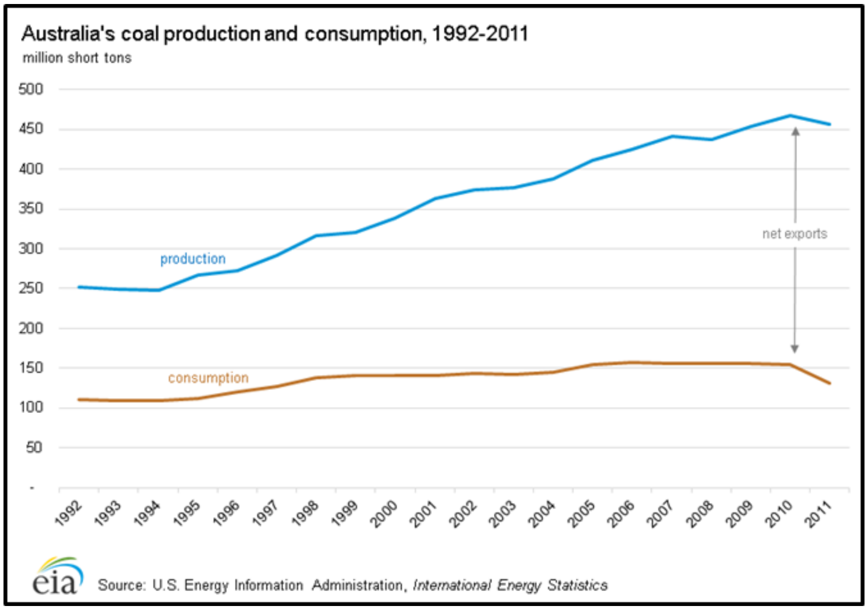

FIGURE 2: Australia's coal production and consumption, 1992-2011 [4]

Coal bed methane (CBM) is becoming one of the interesting field that keep increasing in the petroleum industry recent years. In fact, this coal seam gas were one of the early gas reservoir to be discovered and recover and the most recent to be exploited especially in Australia, China and United States and it has been emerged as one of the significant source of energy all around the globe. Indeed, it is relatively one of the new stream in petroleum engineering and the recovering potential of this natural gas is looking ever more likely as the current conventional gas level keep depleting from time to time. Hence, here comes the coal seam gas to reduce the dependent on the conventional energy sources and the interest to develop this gas is growing even larger in order to provide us, yet another source of energy. Figure 3 on the other side shows the increment of the coal seam gas production in United States.

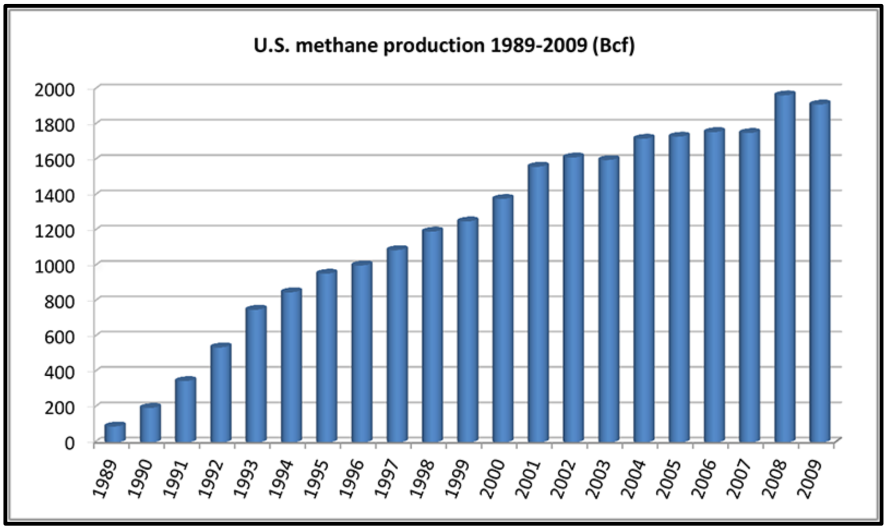

FIGURE 3: United State methane production [5]

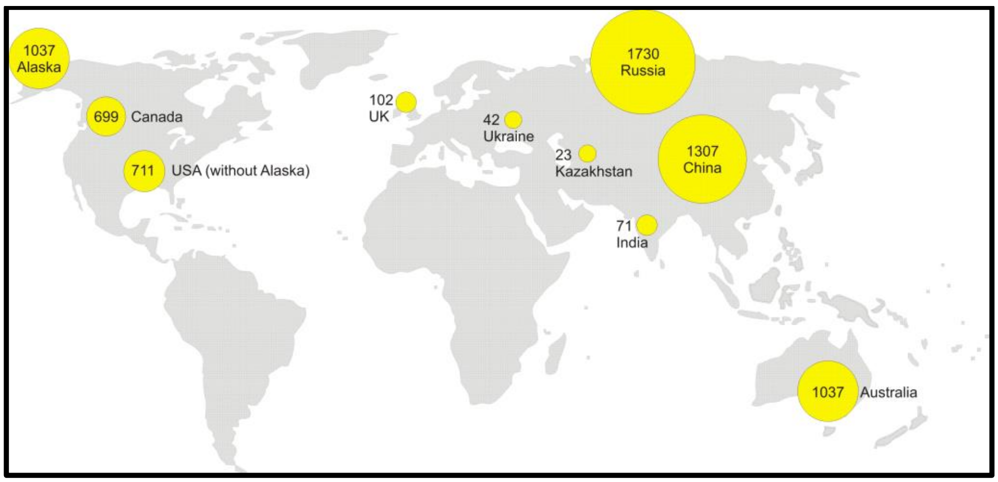

FIGURE 4: Coal seam gas reserves and activity [6]

Based on the figure 4 above, major coal bed methane reserves are mainly found in Russia, United States, China and Australia. USA has largest proven recoverable reserves of coal with 28.6%. Russia becomes second with 18.5% followed by China, Australia and India with 13.5%, 9.0% and 6.7% respectively [5].

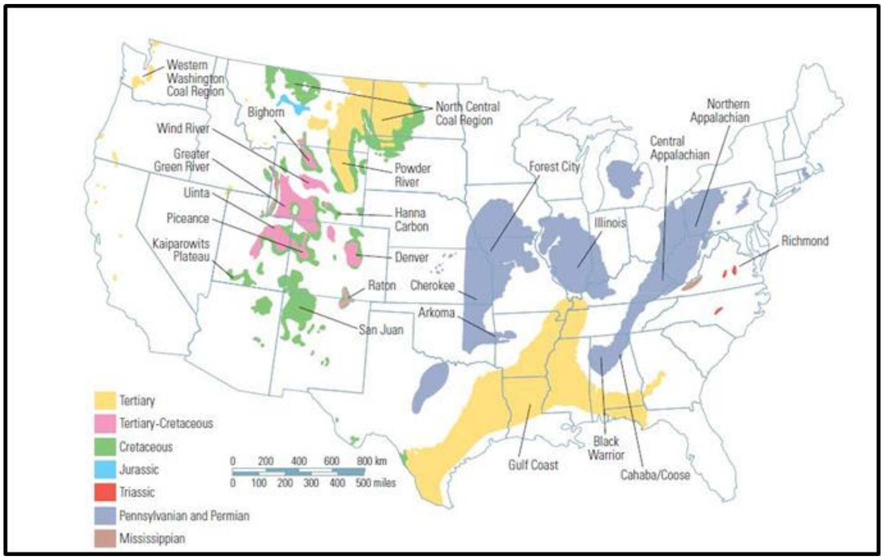

FIGURE 5: United States coal basin [7]

2.3. Shallow coal bed methane well

One of the real advantage of coal seam gas extraction is its reservoir depth which is lower in depth compare to the conventional gas reservoir, with its depth is mainly ranging from 300 to 1500 meters normally resulting into lower pressure of the formation and the stress of the matrix as well as the gradient of the overburden pressure which is about 9×10-3 MPa/m [8]. For instance, the coal seam overburden pressure is 9 MPa at a depth of 1000 m. On the other hand, the conventional gas reservoirs are mostly beyond 2000 m in depth and having gradient of overburden pressure about 11 × 10-3 MPa/m which is about 22 MPa at 2000 m in depth.

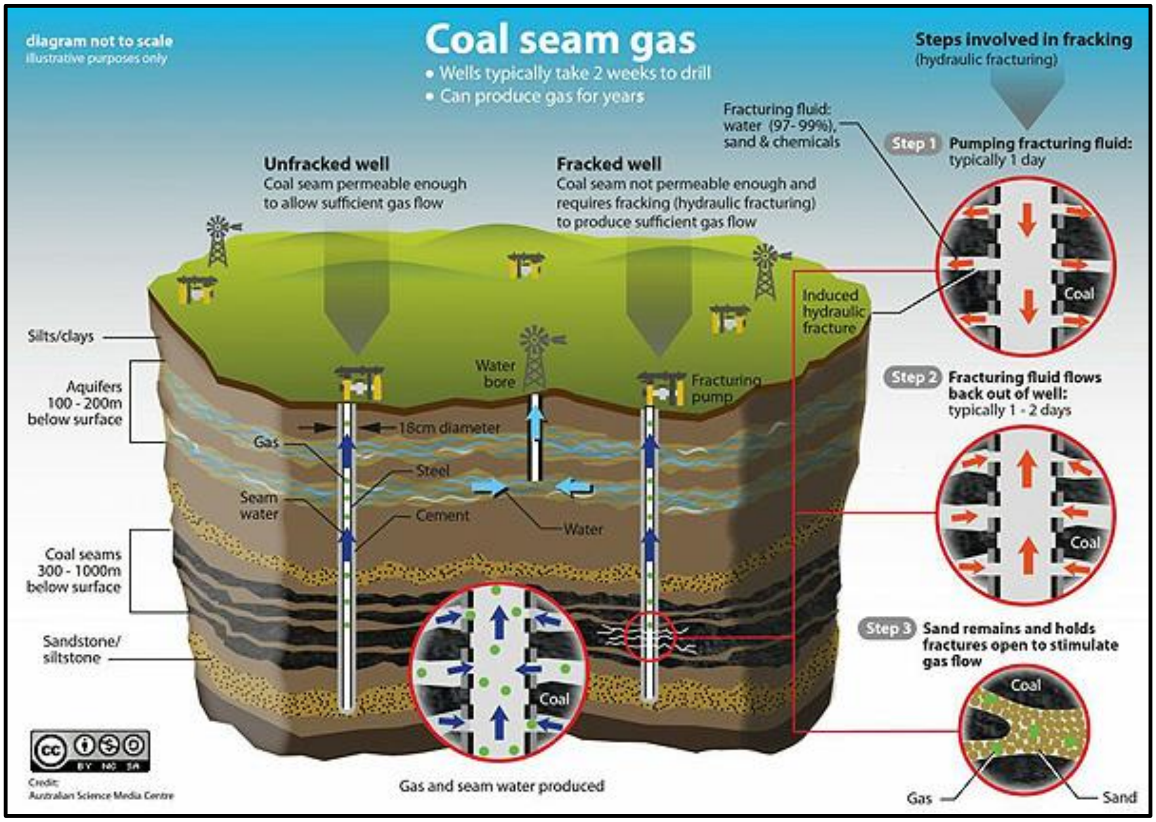

FIGURE 6: Coal seam gas [9]

2.4. Coal bed methane well problem

One of the real advantage of coal seam gas extraction is its reservoir depth which is lower in depth compare to the conventional gas reservoir, with its depth is mainly ranging from 300 to 1500 meters normally resulting into lower pressure of the formation and the stress of the matrix [8]. Due to its shallower depth compare to the conventional gas well, CBM well has been developed throughout the years as the alternative of the conventional gas and perhaps, within years, this type of gas will become the main source of energy for all around the globe. The CBM well completion method which mainly consist of casing cementing, perforation and fracturing, integrated completion and then into the production stage may cause several damages to the well and also can cause into the sand production problem, which the main concern of drilling the well. The production of sand can cause a lot of problem such as equipment corrosion or failure and even worst can even kill the well due to blockage. The usage of sand control either mechanically or chemically is important in tackling such problem. For example, the usage of screen pipe which solve the sand problem mechanically by screening the fluid and block the sand from penetrating into the wellbore. The screen completion method is effectively can prevent the sand from penetrate into the wellbore and the collapse of borehole in an unconsolidated formation reservoir. Basically, the screen pipe is made up of the steel which is known for its high cost. Thus, the total of the well completion cost will be high. So, by the introduction of non-metallic usage such as PVC screen pipes, the well completion cost will be lesser and revenue can be maximized because the non-metallic pipe is lower in cost compare to the metallic.

2.5. Sand Control

Unconsolidated reservoirs with 0.5 – 8 Darcies of permeability are most likely to have sand production problem [10]. Thus, coal bed methane well which have permeability relatively within that range will also facing the same problem besides the coal bed well is literally unconsolidated well. According to Halliburton, sand control is defined by; the essential to the reliable of production in reservoirs where sand exist and being produced, thus creating a major challenge to the production of a well. The industry have spent billions of dollars in preventing and mitigating sand-related problems as these problems could affect the production rates, sand bridging problem, equipment failure and also problem in sand disposal and removal. Sand control methods can divided into two major methods which are mechanically and chemically. In mechanical sand control consists of screening and filtering, for instance the usage of screen pipe and gravel packing respectively. But, in chemical sand control consists of formation chemically consolidation, for instance the usage of resin coated gravel in ‘sticking up’ the formation together and prevent the sand penetrate into the wellbore.

2.6. Screen completion in coal bed methane well

Generally, in conventional oil-gas wells, steel screen is often being used as the part of the well completion in order to increase the area of percolation and for the sand management and it also being used in tackling the hole blockage problem caused by the released dust and the possible collapsing of the well hole due to the CBM formation brittleness factor [11] and the same type of completion also being used in coal bed methane well as well because of unconsolidated reservoir and it is one of the effective method of completion for coal bed wells [8]. However, due to low overburden pressure gradient and overburden pressure (about a quarter of conventional oil-gas wells), non-metallic screen with low strength might can be used for the completion in order to reduce the total well completion cost [8].

2.7. Screen pipes/slotted liners

The screen pipes/slotted liner is the pipe or casing that is positioned within the level of the producing, to prevent the inflow of unwanted particles into a wellbore while allowing the inflow of hydrocarbon. The pipe/screen/liner consists of cutting rectangular openings with small rotary saws and it is normally having slot width within 0.030” or larger and the smallest slot width that can be reached is about 0.012 in. Generally, the longitudinal pattern is preferred more due to its non-slotted area of pipe strength is preserved and this pattern also provides a better uniform slots distribution on the pipe surface are. Basically, there two slot types which are the straight and keystone slot. The different of these slots is the width inside and outside of the pipe. Keystone is the best type of slot because it is less prone to be plugged and permit the hydrocarbon to flow without stuck at plugging [12].

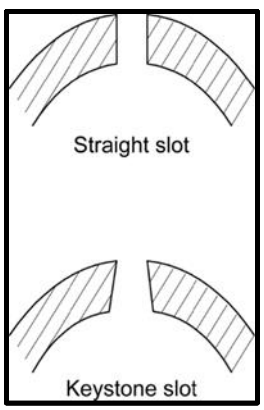

FIGURE 7: Type of slot [12]

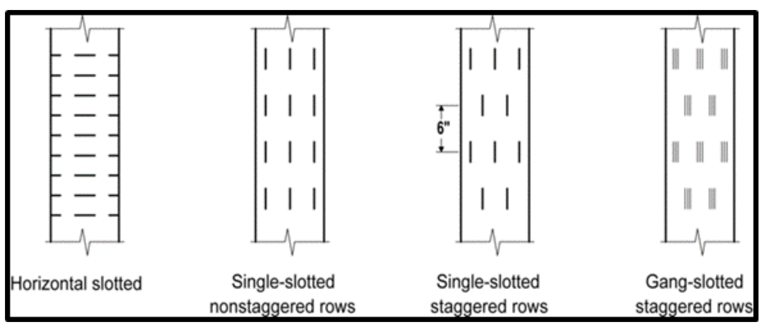

FIGURE 8: Type of slot arrangements [12]

2.8. Polyvinyl Chloride (PVC) Schedule 80 pipe

Sch. 80 pipe is one of the pipe which is resistant to the most acids, alkalis, salts, oxidants, and halogens. It is mostly used in chemical processing, treated and untreated effluent, and underground piping system. The pipe have good resistance to chemical which allows to transport the acids, alkalis and concentration of chemical without fear of corrosion and pollution to the environment. It also has exceptionally smooth bore results in a low friction head losses and inhibit the scale formation and it is 5 times lighter than the steel pipe of the same size and much easier in handling during the installation. The specifications of the pipe are shown in the figure 9 below.

PRODUCT CODE	NOMINAL DIAMETER		PIPE LENGTH	OUTSIDE DIAMETER		WALL THICKNESS		MAX WORKING PRESS	
	(in)	(mm)	L (M)	(in)	(mm)	(in)	(mm)	(psi)	(MPa)
1100 015 60 80	½	15	6.0	0.836 - 0.844	21.2 - 21.4	0.147 - 0.167	3.7 - 4.2	850	5.86
1100 020 60 80	¾	20	6.0	1.046 - 1.054	26.6 - 26.8	0.154 - 0.17	3.9 - 4.4	690	4.76
1100 025 60 80	1	25	6.0	1.310 - 1.320	33.3 - 33.5	0.179 - 0.200	4.6 - 5.1	630	4.34
1100 032 60 80	1¼	32	6.0	1.655 - 1.665	42.0 - 42.3	0.191 - 0.214	4.9 - 5.4	520	3.59
1100 040 60 80	1½	40	6.0	1.894 - 1.906	48.1 - 48.4	0.200 - 0.224	5.1 - 5.7	470	3.24
1100 050 60 80	2	50	6.0	2.369 - 2.381	60.2 - 60.5	0.218 - 0.244	5.5 - 6.2	400	2.76
1100 065 60 80	2½	65	6.0	2.868 - 2.882	72.8 - 73.2	0.276 - 0.309	7.0 - 7.8	420	2.90
1100 080 60 80	3	80	6.0	3.492 - 3.508	88.7 - 89.1	0.300 - 0.336	7.6 - 8.5	370	2.55
1100 100 60 80	4	100	6.0	4.491 - 4.509	114.1 - 114.5	0.337 - 0.377	8.6 - 9.6	320	2.21
1100 155 60 80	6	155	6.0	6.614 - 6.636	168.0 - 168.6	0.432 - 0.484	11.0 - 12.3	280	1.93
1100 200 60 80	8	200	6.0	8.610 - 8.640	218.7 - 219.5	0.500 - 0.560	12.7 - 14.2	250	1.72
1100 250 60 80	10	250	6.0	10.735 - 10.765	272.7 - 273.4	0.593 - 0.664	15.1 - 16.9	230	1.59
1100 300 60 80	12	300	6.0	12.735 - 12.765	323.5 - 324.2	0.687 - 0.769	17.5 - 19.5	230	1.59

FIGURE 9: Pipes dimensions and working pressures

2.9. Collapse strength

Collapse strength is a point where the casing or pipe will experience collapse as the external pressure is higher than internal pressure. When the external pressure on the pipe exceeds the internal pressure, it is then subject to collapse. Collapse is primarily dependent on the Yield Strength of the Material and the slenderness ratio - D/t. There are four type of collapse regimes determined by yield strength and D/t.

- Yield Strength Collapse
- Plastic Collapse
- Transition Collapse

- Elastic Collapse

2.10. Bending strength

Bending strength or also known as flexural strength, fracture strength or rupture modulus, one of the mechanical parameter for the brittleness of the material, is define as the ability of the material to resist the deformation/form-changing under certain load [13]. Measuring the flexural strength of the rectangular sample under one load in a three-point bending setup.

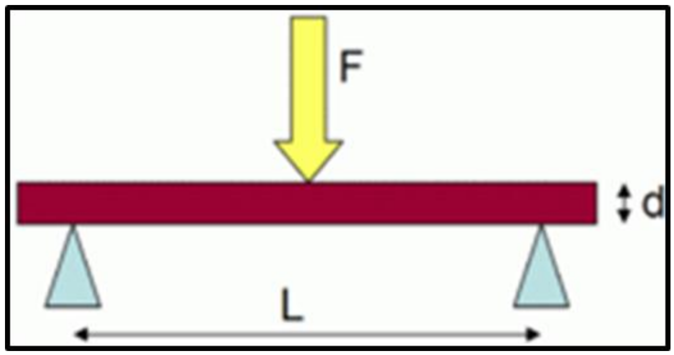

FIGURE 10: Bending strength testing [13]

$$\sigma = \frac{3FL}{2bd^2}$$

- σ, bending stress, psi
- F, load (force) at the fracture point (N)
- b, width (mm)
- d, thickness (mm)

CHAPTER 3

METHODOLOGY

FIRST STAGE

Research

- Information gathering
- Case studies
- Lab manual
- Journals and paper

SECOND STAGE

Preparation

- Specimen preparation
- Measuring and fabrication of the slot
- Equipment preparation (Universal Testing System)

THIRD STAGE

Experimenting

- Collapse resistance testing using Universal Testing System

FOURTH STAGE

Analysis

- Slot density and collapse resistance
- Slot width and collapse resistance
- Cost comparisons
- Conclusion and recommendation

3.1. Research Methodology

Gathering information regarding the project from different type of sources such as the, research papers, journals, websites and others. Most of the papers come from Society of Petroleum Engineers (SPE) and Science Direct and past research paper/thesis. They contain lot of information that can be used throughout the project, for example the case studies.

The case studies:

1. San Juan Basin, New Mexico
2. Powder River Basin, Southern Wyoming
3. Sarawak Coalfield, Malaysia

Lab Manuals:

1. Bending Strength Test
2. Collapse Strength Test

3.2. Data and Specimen Gathering

The pipes are being cut into one feet per specimen and then, the pipes will be fabricated to make the slots. The pipes will be in 3” OD, 1ft in length, and 0.21” in thickness, fulfilling the API standard for a production tubing. UPVC Pipe Schedule 80

FIGURE 11: Slotted PVC pipe

3.3. Laboratory Testing

After fabrication activity is done, the fabricated pipes will go through collapse resistance test using Universal Testing System (UTS). The force will be applied onto the pipe until the pipe shows the crack and collapse. Throughout the test, the data will be tabulated in the given table and later on to be used in analyzing part. A total of 12 units of PVC will be used in this experiment.

3.3.1. Variable Parameters

- Slot width : 0.3mm, 0.4mm, 0.5mm, 0.6mm
- Slot density: 50 slots/ft, 100 slots/ft, 150 slots/ft

3.3.2. Material and Equipment

- 12 ft UPVC pipe Schedule 80 (1ft per specimen, 12 specimen)
- Measuring tools, tape, ruler, marking tools
- Cutting tools to make slot such as chisel, jigsaw and hand drill
- Universal Testing System (UTS)

3.3.3. Data Tabulation

TABLE 2: Specimen data

Description	Pipe #1	Pipe #2	Pipe #3
Thickness, t (mm)			
Diameter, d (mm)			
Length, L (m)			
Surface Area, A (mm^2)			
Force applied, F (kN)			
Pressure Exerted, p (MPa)			

TABLE 3: Data Tabulation

Slot density (slot/ft)	Slot width (mm)	Pressure (Mpa)	Pressure (psi)	Remarks
50	0.3			
	0.4			
	0.5			
	0.6			
Slot density (slot/ft)	Slot width (mm)	Pressure (Mpa)	Pressure (psi)	Remarks
100	0.3			
	0.4			
	0.5			
	0.6			
Slot density (slot/ft)	Slot width (mm)	Pressure (Mpa)	Pressure (psi)	Remarks
150	0.3			
	0.4			
	0.5			
	0.6			

3.3.4. Experiment Procedure

a. Arrange the specimen accordingly, slot width and slot density.

b. Take the specimen. Collect the data which is the slot width and slot density and tabulate into the table. Mark on the location where the load/pressure will be applied under three-point bending.

c. Put the specimen into the Universal Testing System (UTS) (as shown in figure 12 below) and prepare to apply pressure on the pipe.
d. Apply the pressure onto the pipes until the pipe is crack and broken off.
e. Take the point of failure (point at which the pipe is broken off or collapse) and tabulate into the table.
f. Repeat the steps above with different slot width and slot density

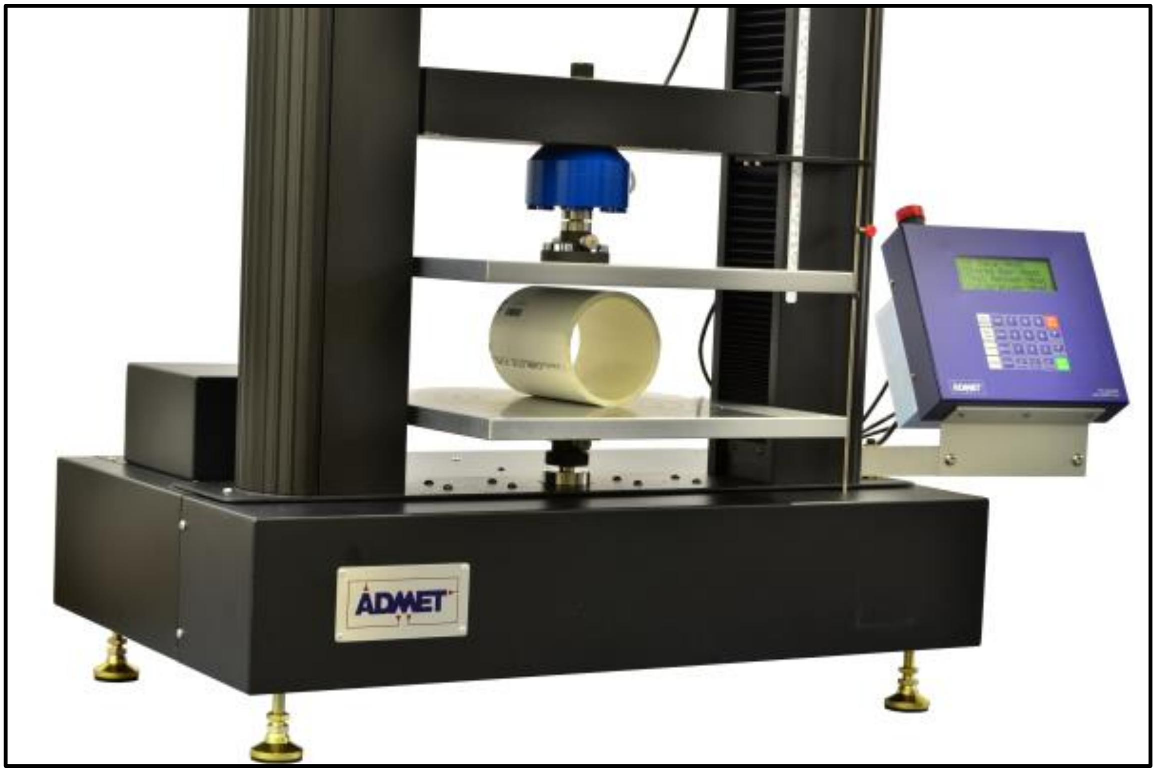

FIGURE 12: Testing the PVC pipe

3.4. Data Analysis

After the experiment has been conducted and all of the data have been obtained, then the data will be used in analyzing part. The pipe will be analyzed based on the minimum and maximum collapse pressure of the pipe, the relationship between slot width and density with the collapse pressure, the suitability of the specimen to be installed in three case studies and also the comparison of the economic part.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. First case study – San Juan basin

TABLE 4: San Juan basin data

CHARACTERISTICS	VALUE
Coal seam thickness	29.527ft
Top of coal seam	4112.8ft
Permeability	3.65md
Porosity of natural fracture system	0.1%
Effective of coal compressibility	$1.0 \text{ X } 10^{-6} psia^{-1}$
Reservoir temperature	113F
Reservoir pressure	1109.5psia
Water saturation	59.2%
Coal density	$89.5 lb/ft^3$
Coal moisture content	6.72%
Coal ash content	15.6%
Langmuir pressure	4688.5psia
Langmuir volume	486scf/ton
Tubing liner size	3”
Mud weight	5.15ppg

Collapse Pressure for Production Casing

At surface, the collapse pressure will zero because the total vertical depth (TVD) equal to zero. At the casing seat, considering the target total vertical depth (TVD) is the sum of coal seam thickness and the depth from surface to the top of the coal seam which is 4142.38 ft, the collapse pressure will be:

$$P_{collapse} = (EMW + SF)(0.052)(TVD)$$

Where:

EMW – Equivalent Mud Weight

SF – Safety Factor (0.5)

0.052psi/ft – conversion factor from lb/gal to psi/ft

TVD – Total Vertical Depth

$$(5.15 + 0.5)(0.052)(4142.38) = \mathbf{1217.05\boldsymbol{psig}}$$

So, the collapse pressure required for the production casing in Sarawak coalfield will be 1217.05 psig.

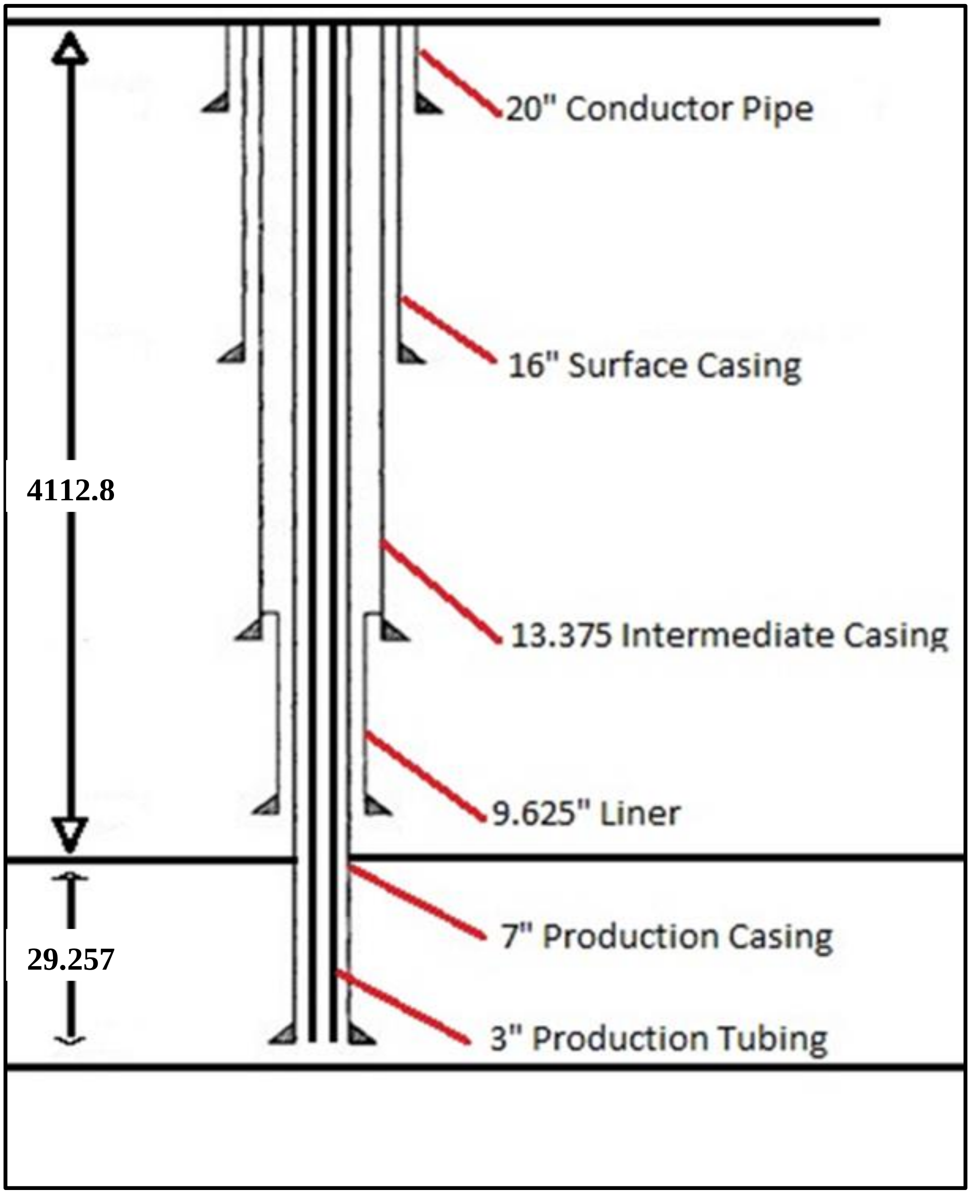

FIGURE 13: Example of CBM well completion - San Juan basin

The figure 13 above shows the picture of the example of coal bed methane well completion in San Juan basin. It just want to show the idea of the completion. The real completion might be different in term of the design.

4.2. Second case study – Powder River basin

TABLE 5: Powder River basin data

CHARACTERISTIC	VALUE
Coal seam thickness	64ft
Top of coal seam	557ft
Permeability	632md
Porosity of natural fracture system	2%
Effective of coal compressibility	1.0 X $10^{-6}psia^{-1}$
Reservoir temperature	65F
Reservoir pressure	152.5psia
Water saturation	50%
Coal density	$83.34/ft^3$
Coal moisture content	27.49%
Coal ash content	4.40%
Langmuir pressure	394psia
Langmuir volume	116.8scf/ton
Tubing liner size	3”
Mud weight	4.72ppg

Collapse Pressure for Production Casing

At surface, the collapse pressure will zero because the total vertical depth (TVD) equal to zero. At the casing seat, considering the target total vertical depth (TVD) is the sum of coal seam thickness and the depth from surface to the top of the coal seam which is 621 ft, the collapse pressure will be:

$$P_{collapse} = (EMW + SF)(0.052)(TVD)$$

$$(4.72 + 0.5)(0.052)(621) = \mathbf{168.56\ psig}$$

So, the collapse pressure required for the production casing in Powder River basin will be 168.56 psig in 621ft in vertical depth.

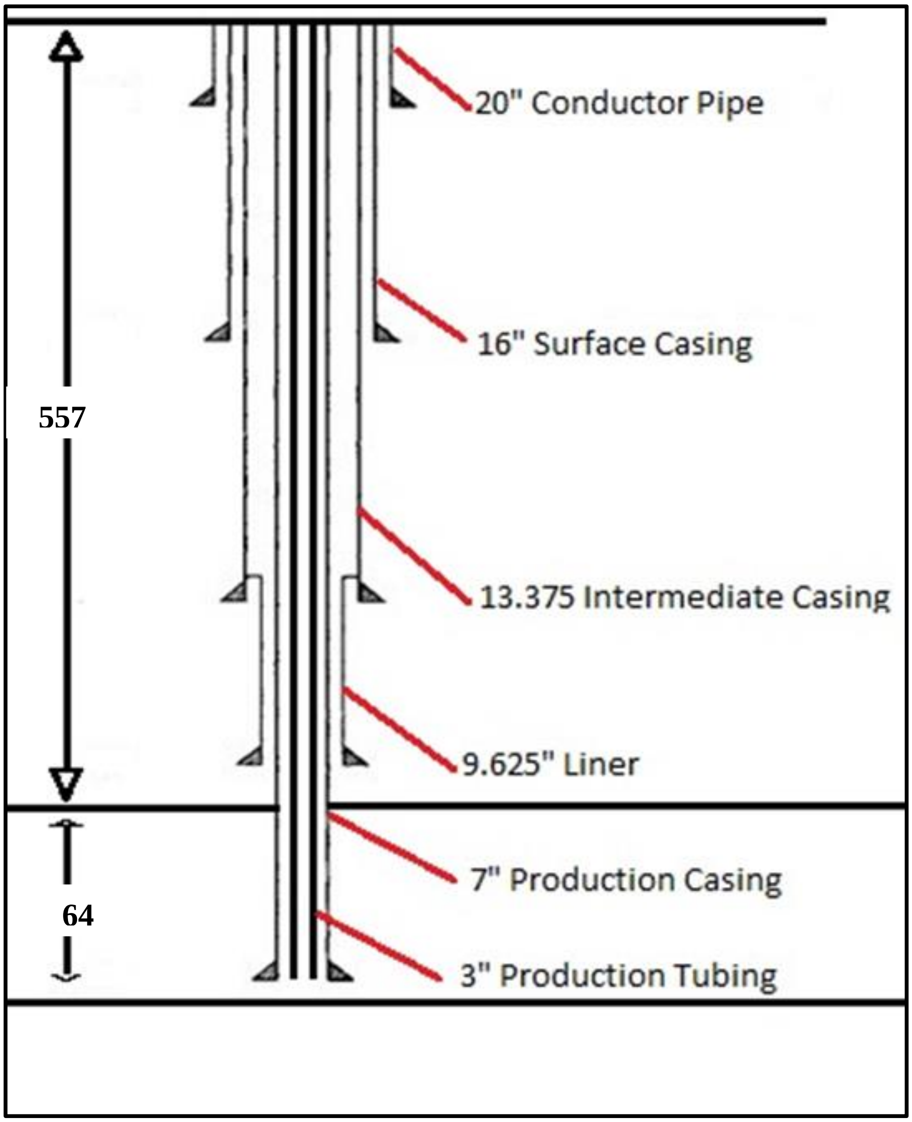

FIGURE 14: Example of CBM well completion – Powder River basin

The figure 14 above shows the picture of the example of coal bed methane well completion in Powder River basin. It just want to show the idea of the completion.

4.3. Third case study – Sarawak coalfield

TABLE 6: Sarawak coalfield data

ITEMS	Value
Coal seam thickness	24.25ft
Top of coal seam	660ft
Permeability	14.42md
Porosity of natural fracture system	3.6%
Effective of coal compressibility	1.0 X 10^{-6}psia^{-1}
Reservoir temperature	75F
Reservoir pressure	200psia
Water saturation	50%
Coal density	83.34/ft^3
Coal moisture content	24.25%
Coal ash content	5.95%
Langmuir pressure	1024.5psia
Langmuir volume	714.29scf/ton
Tubing liner size	3"
Mud weight	5.62ppg

Collapse Pressure for Production Casing

At surface, the collapse pressure will zero because the total vertical depth (TVD) equal to zero. At the casing seat, considering the target total vertical depth (TVD) is the sum of coal seam thickness and the depth from surface to the top of the coal seam which is 621 ft, the collapse pressure will be:

$$P_{collapse} = (EMW + SF)(0.052)(TVD)$$

$$(5.62 + 0.5)\ x\ 0.052\ x\ 684.25 = \mathbf{217.76}\ \boldsymbol{psig}$$

So, the collapse pressure required for the production casing in Sarawak coalfield for 684.25ft in depth will be 217.76 psig.

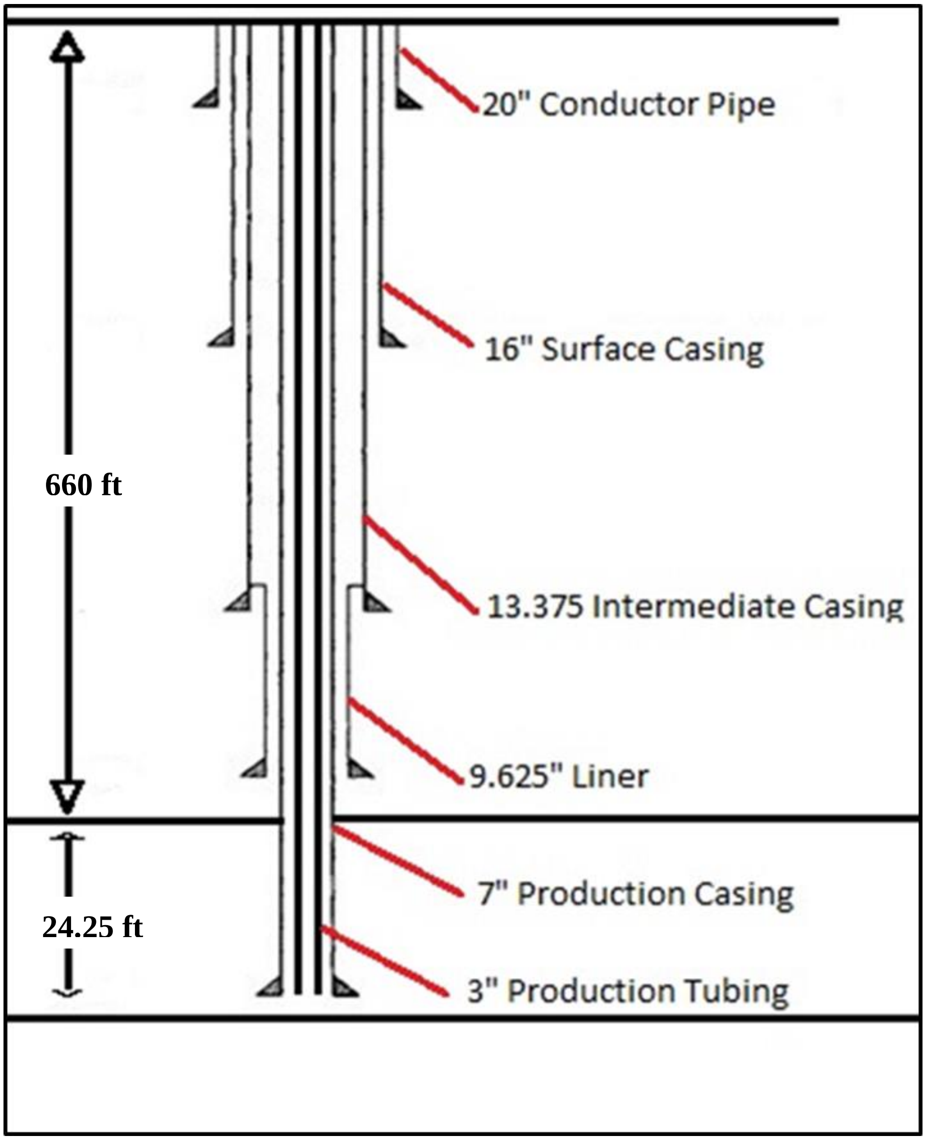

FIGURE 15: Example of CBM well completion – Sarawak coalfield

The figure 15 above is the idea of the well completion as it shows the design of the completion and what casing will be installed. The real design of the completion might be different in terms of the installation of other equipment, the casing arrangement and others.

4.4. Data Analysis

4.4.1. 50 slot/ft

TABLE 7: Data tabulation (50 slot/ft)

Slot density (slot/ft)	Slot width (mm)	Pressure (MPa)	Pressure (psig)	Availability		
				Case #1 San Juan Basin (1217.02 psig)	Case #2 Powder River Basin (168.56 psig)	Case #3 Sarawak Coalfield (217.76 psig)
50	0.3	2.53	366.945381	NO	YES	YES
	0.4	2.47	358.243119	NO	YES	YES
	0.5	2.32	336.487464	NO	YES	YES
	0.6	2.18	316.182186	NO	YES	YES

Based on the table 7 above, the result shows that the pipe can withstand the pressure ranging from 300 psig to 360 psig. The highest pressure which the pipe can withstand is 366.945 psig with 0.3mm in slot width and it has the smallest width of the slot among others. The pipe can be installed in both Powder River and Sarawak coalfield since the required collapse pressure for both field is smaller than the collapse pressure of the pipe for all width of the slot. Unfortunately, the required collapse pressure of San Juan basin is too high for the pipe to withstand, thus it is not possible to install the pipe in that field. The San Juan basin vertical depth is the deepest among other.

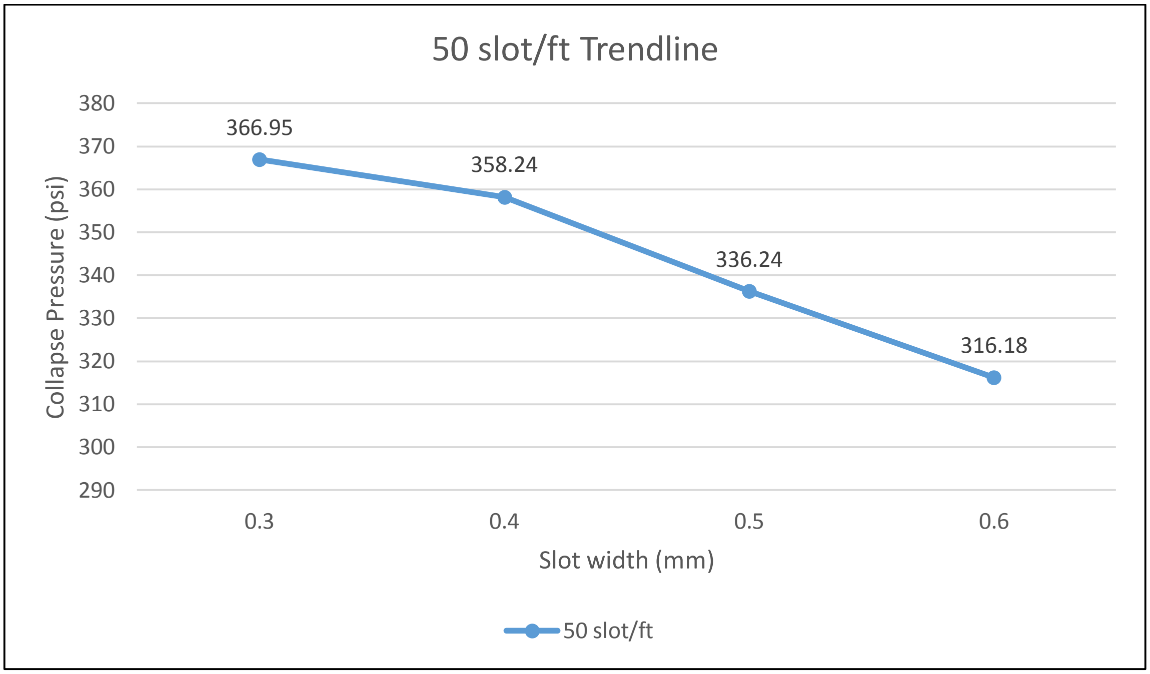

FIGURE 16: 50 slot/ft trend line

The figure 16 above, it shows that the collapse pressure of the pipe is decreased from 0.3mm slot width until 0.6mm slot width with the decrement about 13.84%. As the slot width goes wider, the collapse pressure will go lower.

4.4.2. 100 slot/ft

TABLE 8: Data tabulation (100slots/ft)

Slot density (slot/ft)	Slot width (mm)	Pressure (MPa)	Pressure (psig)	Availability		
				Case #1 San Juan Basin (1217.02 psig)	Case #2 Powder River Basin (168.56 psig)	Case #3 Sarawak Coalfield (217.76 psig)
100	0.3	2.45	355.342365	NO	YES	YES
	0.4	2.39	346.640103	NO	YES	YES
	0.5	2.21	320.533317	NO	YES	YES
	0.6	2.12	307.479924	NO	YES	YES

Based on the table 8 above, the result shows that the pipe can withstand the pressure ranging from 308 psig to 356 psig. The highest pressure which the pipe can withstand is 355.34 psig with 0.3mm in slot width and it has the smallest width of the slot among others. The pipe can be installed in both Powder River and Sarawak coalfield since the required collapse pressure for both field is smaller than the collapse pressure of the pipe for all width of the slot. Unfortunately, the required collapse pressure of San Juan basin is too high for the pipe to withstand, thus it is not possible to install the pipe in that field. The lowest collapse pressure is 307.48 psig.

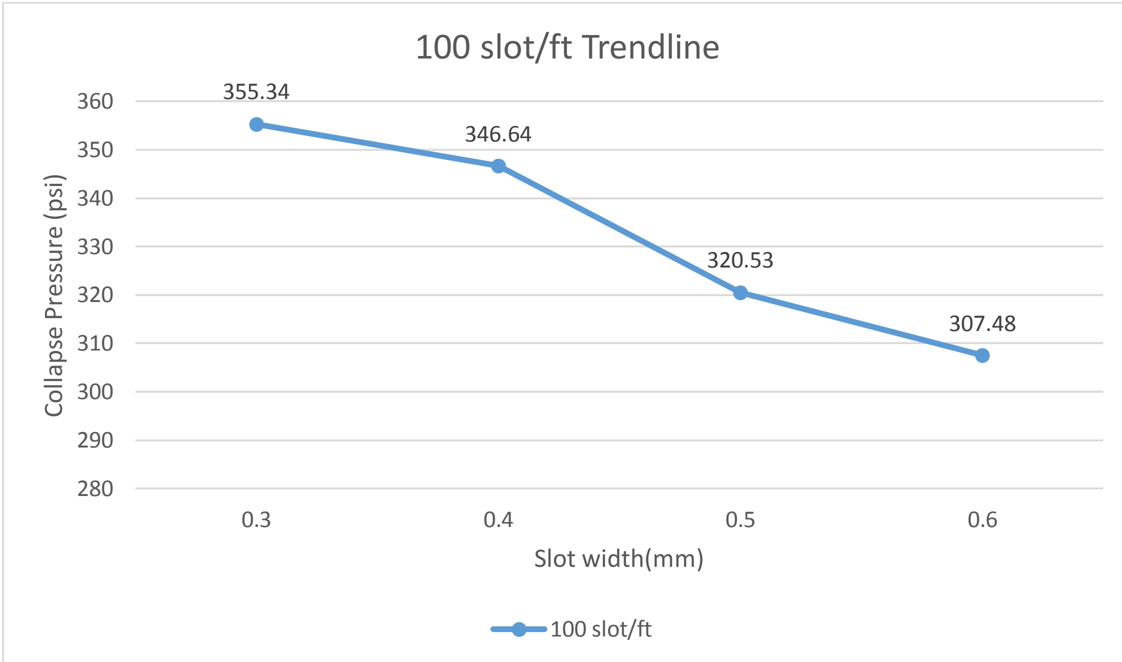

FIGURE 17: 100slot/ft trend line

The figure 16 above, it shows that the collapse pressure of the pipe is decreased from 0.3mm slot width until 0.6mm slot width with the decrement about 13.47%. As the slot width goes wider, the collapse pressure will go lower. The decrement percentage of 50slot/ft and 100slot/ft quite equal to each other and this is because the difference in the surface area for both slot densities is too small.

4.4.3. 150 slots/ft

TABLE 9: Data tabulation (150slots/ft)

Slot density (slot/ft)	Slot width (mm)	Pressure (MPa)	Pressure (psig)	Availability		
				Case #1 San Juan Basin (1217.02 psig)	Case #2 Powder River Basin (168.56 psig)	Case #3 Sarawak Coalfield (217.76 psig)
150	0.3	2.15	311.831055	NO	YES	YES
	0.4	1.97	285.724269	NO	YES	YES
	0.5	1.49	216.106173	NO	YES	NO
	0.6	1.38	200.152026	NO	YES	NO

Based on the table 9 above, the result shows that the pipe can withstand the pressure ranging from 200 psig to 311 psig. The highest pressure which the pipe can withstand is 311.83 psig with 0.3mm in slot width and it has the smallest width of the slot among others. The pipe can be installed in both Powder River and Sarawak coalfield since the required collapse pressure for both field is smaller than the collapse pressure of the pipe for all width of the slot. But for 0.5mm and 0.6mm of the slot width, pipe with both of these slot width cannot withstand the require collapse pressure for Sarawak Coalfield. The required collapse pressure of San Juan basin is too high for the pipe to withstand, thus it is not possible to install the pipe in that field. The lowest collapse pressure is 200.15 psig.

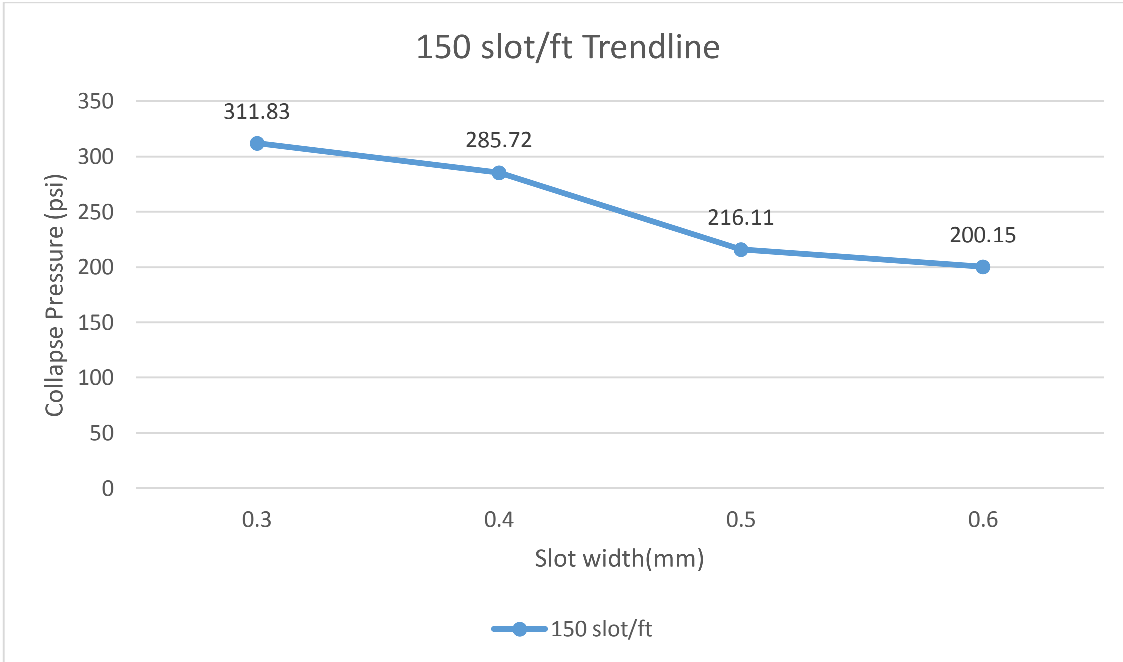

FIGURE 18: 150slot/ft trend line

The figure 16 above, it shows that the collapse pressure of the pipe is decreased from 0.3mm slot width until 0.6mm slot width with the decrement about 35.81%. As the slot width goes wider, the collapse pressure will go lower. The 150slot/ft shows the largest decrement among other densities and this is because, the surface area of the specimen is the lowest compare with the other densities.

4.5. Comparison between the slot densities

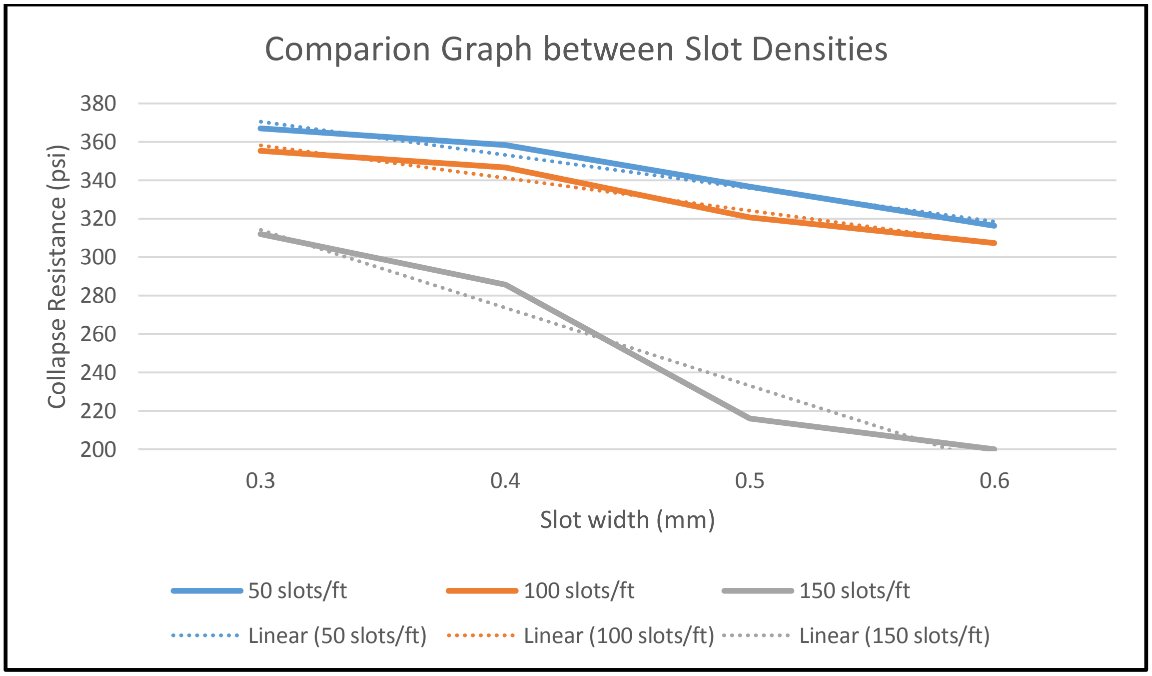

FIGURE 19: Comparison between the slot densities

The figure 19 above shows that the trend of three different slot densities. The pipe with 50 slots/ft and 100 slots/ft show quite the same trend of declination. The pipe with 150 slots/ft shows major declination from 300 psig until below than 220 psig. Based on the graph, it shows that the collapse pressure of the pipe is affected by both slot densities and slot widths. As the width goes wider, or the slot density goes 'denser', the collapse pressure will be lowered. This is due to the reducing exerted area on the surface of the pipe. When the width goes wider, the surface area of the pipe will be lower, then the pressure exerted will be higher. This term is simply can be explained by using simple pressure formula.

$$Pressure, P = \frac{Force, F}{Area, A\ (\pi r^2 h)}$$

$$Pressure\ \alpha\ \frac{1}{Area}$$

The wider the width, the lower the surface area, the lower the pressure that can be withstand by that particular pipe. Based on the graph, the specimen with 150 slots/ft density is having highest decrement percentage which is 35.81% compare with other two, 13.47% (100 slots/ft) and 13.8% (50 slots/ft). Besides that, the linear line of 150 slots/ft shows highest decrement gradient compare with other two.

4.6. Cost estimation

TABLE 10: Cost estimation for the study

ITEM	PVC Pipe (Non-metallic)	Steel Pipe (Metallic)
Cost per foot (RM/ft)	12	48
Length (ft)	12	12
Cost (RM)	144	576
Fabrication (RM)	50	100
Estimation (RM)	**194**	**676**

The table 10 above shows the cost needed to complete this study. These figures do not show the accurate figures or costs of the completion but it only want to show the idea of the huge margin/difference between this two types of material in term of cost. The price of the pipe is based on the domestic price.

For instance, if this two type of pipe is installed in third case study, which is the Sarawak coalfield. The total depth needed is 685ft. The comparison cost between this two types of material will be:

TABLE 11: Example of the cost comparison using third case study

PVC (RM12/ft)	**Steel Pipe (RM48/ft)**
685 ft × RM12/ft	685 ft × RM48/ft
RM8,220	RM3,2880
DIFFERENCE = RM24,660 **About $\frac{1}{4}$ of the total cost can be save.**	

The figure might be real different from the real case but it only wants to show that how much the cost can be saved in order to maximize the revenue in theoretically.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

As for the conclusion, based on the study, it can be concluded that the collapse resistance of the pipe is affected by the density of the slot within the pipe and the width of the slot. The higher the density of the slot, the lower the pipe collapse resistance value and same goes to the width of slot, the wider the width of slot, the lower the pipe collapse resistance value. In the simplest term, both of them are inversely proportional to the collapse resistance value. Thus, the hypothesis is accepted.

$$Collapse\ resistance\ \alpha\ \frac{1}{density\ of\ the\ slot}$$

$$Collapse\ resistance\ \alpha\ \frac{1}{width\ of\ the\ slot}$$

Apart from that, in theoretically, the study also shows that the non-metallic screen pipe can be applied in some low pressure reservoir, for instance, coal bed methane reservoir. The real advantage of using non-metallic screen pipe is the cost of the non-metallic is lower than metallic screen pipe which can help the company to maximizing the revenue of the reservoir.

To summarize all, the hypothesis is accepted and the objective is achieved.

5.2. Recommendation

Since the study is only focusing on the pipe collapse resistance value, the result seems to be less reliable because the study is only focus on the single variable. Therefore, it would be recommended to take into account other variables such as the tension load, biaxial load and even the reservoir temperature for future studies in order to produce more reliable result. Apart from that, it would also recommended to use different sizes of the pipe throughout the experiment in optimizing the best pipe sizing selection as well as to produce more reliable data and also to use a number of specimens in every testing for more accurate result. The next thing is the specimen with high elastic modulus and material density should be used in future to test their collapse strength with higher pressure. Last but not least, a simulation using this type of pipe should be done using software in order to prove the theory of the non-metallic screen pipe usage in coal bed methane well.

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